

TABLE 1

Conditions of Circumferential Surfaces of Cooling Rolls, Grooves and Ridges

	Average Width of Groove L_1 (μm)	Average Width of Ridge L_2 (μm)	Average Depth of Groove L_3 (μm)	Average Pitch L_4 (μm)	Ratio of Projected Area of Grooves (%)
Cooling Roll A	22.5	2.5	3.5	25.0	90
Cooling Roll B	20.0	40.0	3.0	40.0	50
Cooling Roll C	10.0	12.0	1.5	12.0	83
Cooling Roll D	27.0	90.0	8.0	90.0	30
Cooling Roll E	30.0	50.0	2.0	50.0	60
Cooling Roll F	28.0	68.0	5.3	68.0	41
Cooling Roll G	5.0	7.5	1.0	7.5	67
Cooling Roll H	9.5	15.0	2.5	15.0	63
Cooling Roll I	20.0	30.0	1.5	30.0	67
Cooling Roll J	-	-	-	-	-

TABLE 2

Properties of Melt Spun Ribbons (Sample No. 1a to 1e)							(First Embodiment)	
Sample No.	Cooling Roll Used for Manufacturing Melt Spun Ribbons	Average Thickness (μm)	Ratio of Projected Area of Huge Dimples (%)	Ratio of Total Area of Dimples (%)	H _{CJ} (kJ/m)	Br (T)	(BH) _{max} (kJ/m ³)	
This Invention 1a	Cooling Roll A	1	20	2.3		647	0.92	123
		2	19	1.8		649	0.92	126
		3	18	2.4		652	0.91	121
		4	19	1.7		650	0.94	130
		5	20	1.8		648	0.92	124
This Invention 1b	Cooling Roll B	1	21	2.5		638	0.90	119
		2	22	2.3		640	0.91	120
		3	21	2.1		635	0.92	124
		4	21	2.6		625	0.89	115
		5	20	2.4		629	0.90	118
This Invention 1c	Cooling Roll C	1	18	0.2		656	0.96	137
		2	19	0.3		657	0.95	133
		3	19	0.1		660	0.96	139
		4	19	0.3		654	0.95	135
		5	19	0.2		658	0.95	137
This Invention 1d	Cooling Roll D	1	23	4.1		612	0.86	108
		2	19	3.0		623	0.88	114
		3	24	3.9		616	0.86	110
		4	20	3.8		619	0.87	111
		5	22	3.5		620	0.87	112
This Invention 1e	Cooling Roll E	1	23	2.1		642	0.92	124
		2	21	2.0		645	0.93	126
		3	21	2.1		641	0.92	123
		4	21	2.3		635	0.91	120
		5	20	2.4		638	0.90	119

Metal Composition: (Nd_{0.7}Pr_{0.3})_{10.5}Fe_{89.5}B₆

TABLE 3

Properties of Melt Spun Ribbons (Sample No. 1f to 1j)							(First Embodiment)		
Sample No.	Cooling Roll Used for Manufacturing Melt Spun Ribbons	Average Thickness (μm)	Ratio of Projected Area of Huge Dimples (%)	Ratio of Total Area of Dimples (%)	H _{CJ} (kJ/m)	Br (π)	(BH) _{max} (kJ/m ³)		
This Invention 1f	Cooling Roll F	1	21	1.9	18	645	0.93	129	
		2	23	2.3	22	637	0.91	120	
		3	22	1.8	20	643	0.93	127	
		4	22	2.0	23	640	0.93	125	
		5	21	2.2	21	638	0.92	122	
This Invention 1g	Cooling Roll G	1	19	0.4	16	651	0.94	132	
		2	18	0.3	15	653	0.94	133	
		3	18	0.6	17	649	0.94	130	
		4	20	0.2	12	658	0.96	138	
		5	20	0.3	11	655	0.95	135	
This Invention 1h	Cooling Roll H	1	21	1.1	17	644	0.93	127	
		2	21	0.9	17	648	0.94	131	
		3	20	1.3	19	642	0.93	125	
		4	20	1.1	18	646	0.93	129	
		5	21	1.4	21	639	0.92	124	
This Invention 1i	Cooling Roll I	1	20	2.3	24	641	0.91	120	
		2	20	2.1	22	640	0.92	124	
		3	21	2.4	25	635	0.91	118	
		4	23	2.2	22	639	0.92	122	
		5	21	2.5	26	636	0.90	117	
Comp.Ex. 1j	Cooling Roll J	1	30	18.6	45	382	0.69	59	
		2	17	23.1	55	303	0.81	74	
		3	32	20.5	48	376	0.71	62	
		4	23	27.3	60	340	0.72	65	
		5	19	16.2	50	328	0.75	68	

Metal Composition: (Nd_{0.7}Pr_{0.3})_{10.5}Fe_{89.5}B₆

TABLE 4

Average Crystal Grain Size of Hard Magnetic Phase and

Melt Spun Ribbon Sample No.	Magnetic Properties of Bonded Magnet (First Embodiment)		
	Average Crystal Grain Size (nm)	H _{ci} (kA/m)	Br (T)
This Invention 1a	32	648	0.78
This Invention 1b	38	631	0.77
This Invention 1c	25	655	0.81
This Invention 1d	40	615	0.75
This Invention 1e	37	643	0.77
This Invention 1f	30	639	0.79
This Invention 1g	27	650	0.80
This Invention 1h	28	642	0.80
This Invention 1i	34	638	0.78
Comp.Ex 1j	65	345	0.62
			(BH) _{max} (kJ/m ³)
			89
			83
			98
			80
			86
			88
			95
			92
			85
			41

Metal Composition: (Nd_{0.7}Pr_{0.3})_{10.5}Fe_{89.5}B₆

TABLE 5

Properties of Melt Spun Ribbons (Sample No. 2a to 2e)							(Second Embodiment)		
Sample No.	Cooling Roll Used for Manufacturing Melt Spun Ribbons	Average Thickness (μm)	Ratio of Projected Area of Huge Dimples (%)	Ratio of Total Area of Dimples (%)	H_{CI} (kJ/m)	Br (T)	$(BH)_{max}$ (kJ/m ³)		
This Invention 2a	Cooling Roll A	1	1.9	19	852	0.89	127		
		2	2.3	24	845	0.87	121		
		3	2.1	20	848	0.88	125		
		4	2.0	21	851	0.88	127		
		5	2.5	26	843	0.87	122		
This Invention 2b	Cooling Roll B	1	2.4	22	838	0.85	115		
		2	2.7	25	844	0.84	113		
		3	2.6	26	842	0.85	115		
		4	2.7	24	837	0.83	111		
		5	2.2	25	839	0.85	117		
This Invention 2c	Cooling Roll C	1	0.2	11	854	0.91	133		
		2	0.4	16	853	0.90	130		
		3	0.2	12	860	0.91	136		
		4	0.1	9	858	0.91	134		
		5	0.3	14	852	0.90	131		
This Invention 2d	Cooling Roll D	1	3.2	31	820	0.83	110		
		2	4.3	37	813	0.81	104		
		3	3.9	36	822	0.82	106		
		4	3.6	33	818	0.83	108		
		5	4.2	35	817	0.82	107		
This Invention 2e	Cooling Roll E	1	2.2	23	845	0.87	123		
		2	2.1	22	841	0.87	124		
		3	2.4	28	836	0.86	122		
		4	2.6	25	839	0.86	118		
		5	2.3	21	842	0.86	121		

Metal Composition: Nd_{11.5}Fe_{84.5}B_{4.0}

TABLE 6

Properties of Melt Spun Ribbons (Sample No. 2f to 2j)								(Second Embodiment)	
Sample No.	Cooling Roll Used for Manufacturing Melt Spun Ribbons	Average Thickness (μm)	Ratio of Projected Area of Huge Dimples (%)	Ratio of Total Area of Dimples (%)	H _{CJ} (KA/m)	Br (°)	(BH) _{max} (kJ/m ³)		
This Invention 2f	Cooling Roll F	1	23	2.0	18	838	0.88	125	
		2	22	2.1	19	842	0.87	124	
		3	22	2.3	23	836	0.87	123	
		4	24	2.2	22	846	0.88	127	
		5	23	2.5	24	841	0.86	121	
This Invention 2g	Cooling Roll G	1	21	0.7	14	850	0.89	129	
		2	21	0.5	16	853	0.90	132	
		3	20	0.4	13	847	0.91	133	
		4	19	0.3	11	856	0.91	135	
		5	19	0.5	12	853	0.90	130	
This Invention 2h	Cooling Roll H	1	21	1.2	20	842	0.87	120	
		2	22	1.5	19	846	0.86	116	
		3	22	1.1	21	839	0.87	122	
		4	22	1.3	19	843	0.86	118	
		5	21	1.4	18	847	0.85	115	
This Invention 2i	Cooling Roll I	1	22	2.3	25	835	0.86	117	
		2	21	2.7	28	831	0.85	115	
		3	21	2.2	24	840	0.86	120	
		4	22	2.6	27	835	0.84	113	
		5	24	2.4	24	832	0.85	116	
Comp.Ex. 2j	Cooling Roll J	1	19	22.5	52	375	0.73	62	
		2	33	16.5	44	453	0.66	55	
		3	17	24.2	58	386	0.71	64	
		4	34	17.7	49	463	0.63	51	
		5	22	27.8	63	395	0.68	56	

Metal Composition: Nd_{11.5}Fe_{88.5}B_{0.6}

TABLE 7

Average Crystal Grain Size of Hard Magnetic Phase and

Melt Spun Ribbon Sample No.	Magnetic Properties of Bonded Magnet (Second Embodiment)		
	Average Crystal Grain Size (nm)	H _{CJ} (kA/m)	Br (T)
This Invention 2a	29	847	0.75
This Invention 2b	37	838	0.73
This Invention 2c	26	851	0.77
This Invention 2d	42	819	0.71
This Invention 2e	32	840	0.75
This Invention 2f	30	839	0.75
This Invention 2g	28	852	0.76
This Invention 2h	34	843	0.75
This Invention 2i	36	830	0.74
Comp.Ex 2j	67	390	0.55

Metal Composition: Nd_{11.5}Fe_{88.5}B_{4.6}

TABLE 8

Properties of Melt Spun Ribbons (Sample No. 3a to 3e)							(Third Embodiment)	
Sample No.	Cooling Roll Used for Manufacturing Melt Spun Ribbons	Average Thickness (μm)	Ratio of Projected Area of Huge Dimples (%)	Ratio of Total Area of Dimples (%)	H _{cl} (kA/m)	Br (T)	(BH) _{max} (kJ/m ³)	
This Invention 3a	Cooling Roll A	1	22	2.3		1087	0.84	122
		2	22	1.6		1092	0.85	126
		3	21	1.7		1090	0.85	125
		4	20	2.4		1084	0.84	120
		5	20	1.9		1089	0.84	123
This Invention 3b	Cooling Roll B	1	22	1.9		1068	0.83	118
		2	23	2.4		1062	0.81	113
		3	24	2.3		1065	0.80	111
		4	23	2.2		1065	0.82	115
		5	23	2.2		1061	0.81	114
This Invention 3c	Cooling Roll C	1	21	0.3		1100	0.85	126
		2	20	0.1		1112	0.86	131
		3	21	0.2		1103	0.85	126
		4	22	0.2		1108	0.86	127
		5	21	0.4		1095	0.85	125
This Invention 3d	Cooling Roll D	1	24	3.1		1057	0.79	110
		2	25	4.0		1046	0.78	103
		3	22	3.7		1048	0.78	105
		4	26	3.6		1051	0.79	107
		5	22	3.3		1053	0.79	108
This Invention 3e	Cooling Roll E	1	22	1.8		1079	0.84	124
		2	25	2.0		1080	0.83	121
		3	23	2.1		1076	0.82	118
		4	24	2.2		1075	0.82	117
		5	23	1.9		1078	0.83	122

Metal Composition: $\text{Nd}_{14.2}(\text{Fe}_{0.85}\text{Co}_{0.15})_{\text{bal.}}$ B_{6.8}

TABLE 9

Properties of Melt Spun Ribbons (Sample No. 3f to 3j)							(Third Embodiment)		
Sample No.	Cooling Roll Used for Manufacturing Melt Spun Ribbons	Average Thickness (μm)	Ratio of Projected Area of Huge Dimples (%)	Ratio of Total Area of Dimples (%)	H_{CJ} (kJ/m)	Br (T)	$(BH)_{\text{max}}$ (kJ/m ³)		
This Invention 3f	Cooling Roll F	1	2.2	25	1074	0.82	119		
		2	1.7	20	1076	0.84	126		
		3	1.8	18	1077	0.83	124		
		4	2.0	18	1075	0.83	121		
		5	1.9	21	1073	0.84	123		
This Invention 3g	Cooling Roll G	1	0.5	12	1089	0.85	124		
		2	0.2	10	1096	0.86	127		
		3	0.3	11	1098	0.85	125		
		4	0.3	15	1091	0.83	121		
		5	0.4	13	1093	0.84	123		
This Invention 3h	Cooling Roll H	1	0.8	13	1083	0.85	127		
		2	1.2	15	1081	0.83	123		
		3	1.4	16	1082	0.83	122		
		4	1.1	15	1080	0.85	126		
		5	1.0	17	1078	0.82	121		
This Invention 3i	Cooling Roll I	1	2.0	21	1074	0.82	116		
		2	2.4	26	1070	0.82	120		
		3	2.2	23	1072	0.81	115		
		4	2.4	25	1069	0.82	119		
		5	2.3	24	1071	0.83	122		
Comp.Ex. 3j	Cooling Roll J	1	15.6	43	560	0.61	53		
		2	24.5	56	509	0.64	65		
		3	17.8	49	575	0.60	51		
		4	19.7	52	511	0.67	67		
		5	28.1	61	537	0.62	59		

Metal Composition: Nd_{14.2}(Fe_{0.35}Co_{0.15})_{bal.} B_{0.8}

TABLE 10

Average Crystal Grain Size of Hard Magnetic Phase and
Magnetic Properties of Bonded Magnet (Third Embodiment)

Melt Spun Ribbon Sample No.	Average Crystal Grain Size (nm)	H _{CJ} (kA/m)	Br (T)	(BH) _{max} (kJ/m ³)
This Invention 3a	28	1085	0.71	86
This Invention 3b	36	1060	0.70	80
This Invention 3c	24	1102	0.72	89
This Invention 3d	41	1050	0.66	74
This Invention 3e	32	1078	0.71	82
This Invention 3f	30	1072	0.71	84
This Invention 3g	25	1090	0.72	88
This Invention 3h	27	1081	0.71	86
This Invention 3i	34	1069	0.70	81
Comp.Ex 3j	62	545	0.53	45

Metal Composition: Nd_{1.42}(Fe_{0.85}Co_{0.15})_{bal.} B_{6.8}

TABLE 11

Properties of Melt Spun Ribbons (Sample No. 4a to 4e)								(Comp.Ex.)
Sample No.	Cooling Roll Used for Manufacturing Melt Spun Ribbons	Average Thickness (μm)	Ratio of Projected Area of Huge Dimples (%)	Ratio of Total Area of Dimples (%)	H_{CJ} (kJ/m)	Br (T)	$(BH)_{\text{max}}$ (kJ/m ³)	
Comp.Ex. 4a	Cooling Roll A	1	2.6	25	120	0.80	33	
		2	1.9	21	117	0.79	32	
		3	1.8	19	122	0.80	34	
		4	2.5	24	115	0.80	33	
		5	2.2	20	119	0.80	33	
Comp.Ex. 4b	Cooling Roll B	1	2.3	22	112	0.77	28	
		2	2.8	28	111	0.76	26	
		3	2.4	25	108	0.76	25	
		4	2.7	26	107	0.76	24	
		5	2.6	27	113	0.77	26	
Comp.Ex. 4c	Cooling Roll C	1	0.4	13	125	0.82	36	
		2	0.2	11	122	0.82	35	
		3	0.3	12	127	0.81	34	
		4	0.4	15	130	0.81	34	
		5	0.3	10	123	0.81	33	
Comp.Ex. 4d	Cooling Roll D	1	4.2	38	103	0.71	19	
		2	3.9	35	105	0.72	21	
		3	3.8	35	108	0.72	22	
		4	4.4	37	109	0.70	18	
		5	3.5	32	104	0.71	19	
Comp.Ex. 4e	Cooling Roll E	1	2.3	21	120	0.80	33	
		2	2.5	22	116	0.79	32	
		3	2.6	24	119	0.80	31	
		4	2.2	23	115	0.79	32	
		5	2.1	19	117	0.78	31	

Metal Composition: $\text{Pr}_{13}(\text{Fe}_{98}\text{Co}_{0.2})_{100}\text{B}_{3.5}$

Metal Composition: $\text{Pr}_3(\text{Fe}_{0.8}\text{Co}_{0.2})_{\text{bal}}\text{B}_{3.5}$

TABLE 12

Properties of Melt Spun Ribbons (Sample No. 4f to 4j)							(Comp. Ex.)
Sample No.	Cooling Roll Used for Manufacturing Melt Spun Ribbons	Average Thickness (μm)	Ratio of Projected Area of Huge Dimples (%)	Ratio of Total Area of Dimples (%)	H_{c1} (kA/m)	Br (T)	$(BH)_{\text{max}}$ (kJ/m ³)
Comp. Ex. 4f	Cooling Roll F	1	2.1	23	114	0.78	31
		2	2.0	22	118	0.79	33
		3	2.4	26	116	0.79	33
		4	2.2	21	112	0.78	30
		5	2.6	28	115	0.79	32
Comp. Ex. 4g	Cooling Roll G	1	0.5	15	125	0.80	33
		2	0.3	11	120	0.81	34
		3	0.4	13	121	0.80	33
		4	0.7	16	118	0.80	33
		5	0.4	12	123	0.81	34
Comp. Ex. 4h	Cooling Roll H	1	1.6	18	120	0.80	34
		2	1.4	15	116	0.79	32
		3	1.7	21	118	0.80	33
		4	1.4	16	114	0.79	31
		5	1.2	12	117	0.79	33
Comp. Ex. 4i	Cooling Roll I	1	2.6	26	115	0.77	30
		2	2.4	24	117	0.78	32
		3	2.7	27	114	0.77	31
		4	2.5	26	113	0.77	30
		5	2.2	23	116	0.77	29
Comp. Ex. 4j	Cooling Roll J	1	15.3	46	72	0.61	12
		2	21.2	53	83	0.62	13
		3	26.5	60	69	0.60	11
		4	19.8	48	75	0.62	12
		5	23.2	57	85	0.62	14

Metal Composition: $\text{Pr}_3(\text{Fe}_{0.8}\text{Co}_{0.2})_{\text{bal}}\text{B}_{1.5}$

TABLE 13

Average Crystal Grain Size of Hard Magnetic Phase and

Melt Spun Ribbon Sample No.	Magnetic Properties of Bonded Magnet			(Comp. Ex.)
	Average Crystal Grain Size (nm)	H _{CJ} (kA/m)	Br (T)	(BH) _{max} (kJ/m ³)
This Invention 4a	40	118	0.67	22
This Invention 4b	47	110	0.65	18
This Invention 4c	35	125	0.68	25
This Invention 4d	52	106	0.61	15
This Invention 4e	43	118	0.67	21
This Invention 4f	42	113	0.67	22
This Invention 4g	36	120	0.68	24
This Invention 4h	38	117	0.67	23
This Invention 4i	46	115	0.66	20
Comp.Ex 4j	83	70	0.56	9

Metal Composition: Pr₃(Fe_{0.8}Co_{0.2})₁₀₀B_{3.5}